(12) UK Patent Application (19) GB (11) 2 212 903 (13) A

(43) Date of A publication 02.08.1989

(21) Application No 8727509.5

(22) Date of filing 24.11.1987

(71) Applicant
Rolls-Royce plc

(Incorporated in the United Kingdom)

65 Buckingham Gate, London, SW1E 6AT, United Kingdom

(72) Inventor
Peter Antony Eabry Stewart

(74) Agent and/or Address for Service
V J Bird
Rolls-Royce plc, Patents Department, PO Box 31, Derby, DE2 8BJ, United Kingdom

(51) INT CL⁴
G01N 9/36 23/12

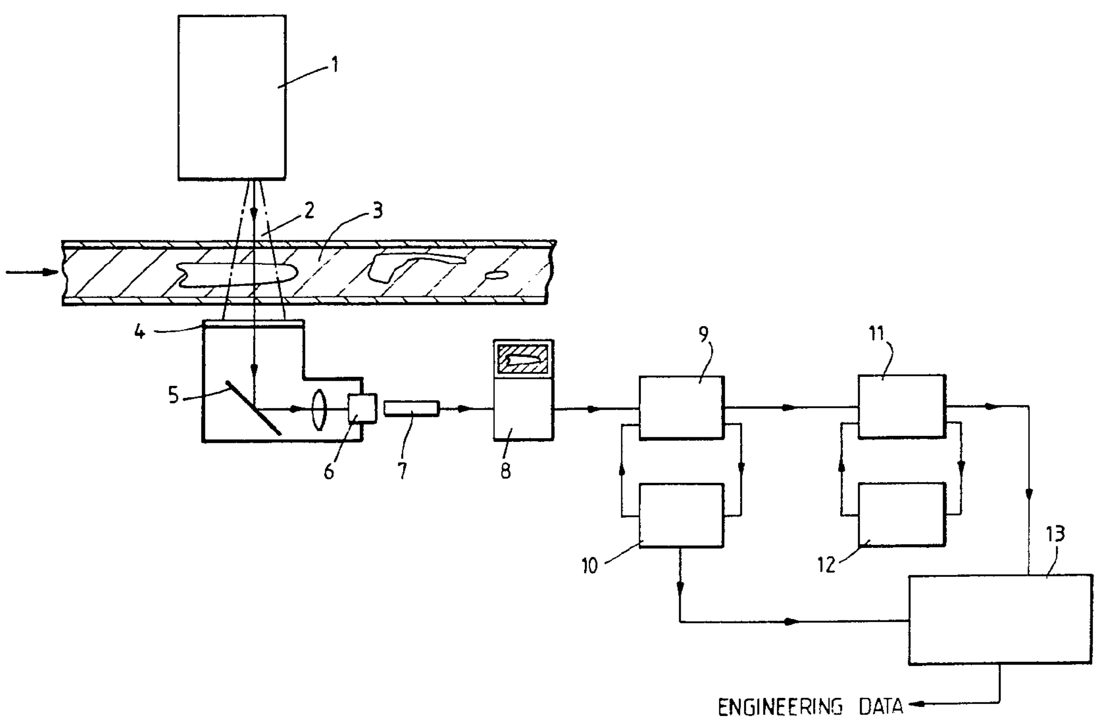
(52) UK CL (Edition J)
G1A AAJ AA11 AA3 AA4 AC1 ADJ AD1 AD10 AD12 AG1 AG10 AG17 AG2 AG7 AG9 AP16 AP17 AR2 AR7 AS10 AS12 AS3 AT1 AT15 AT2 AT20 AT3 AT8
U1S S1248 S1252 S1267 S1269 S1270 S1272 S1449 S1457 S1573 S1754 S1839 S1883 S1884 S1987 S2035 S2149 S2150 S2158 S2159 S2181 S2316

(56) Documents cited
GB 1415643 A **GB 1264009 A** **EP 0183637 A1**
US 4429410 A **US 3749910 A** **US 3621243 A**

(58) Field of search
UK CL (Edition J) **G1A AAJ ADJ AMQ AMZ**
INT CL⁴ **G01N**

(54) **Analyzing two phase flow in pipes**

(57) A section of pipe carrying a material flow is x-rayed using e.g. a stereoscopic imaging system 1, 4, 5, 6, 7, 8 and the images stored, e.g. in a video frame store 9. The stored image data is operated on by an image processing system 10, 11, 12, 13 and information describing the density distribution of material flowing through the imaged section of the pipe is extracted. From this information the type of flow and the relative quantities of gas, liquid and solid is determined. The results are useful for controlling the operation of a pumping system supplying the material in order to cater, for example, for large quantities of gas in the flow. The results also find use in a fiscal metering system in an oil field, and in fuel and lubrication systems for gas turbine engines.

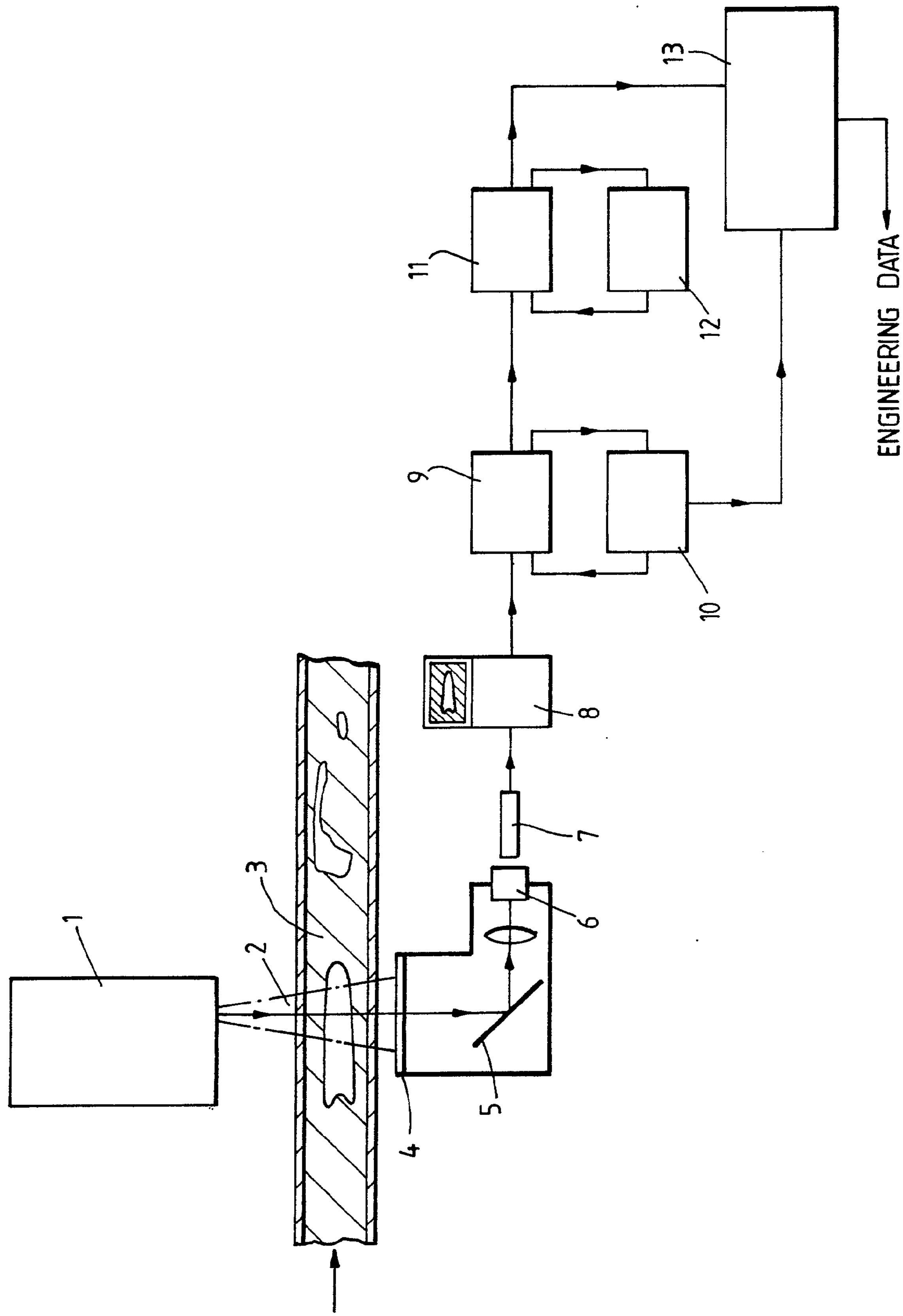


At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 212 903 A

2212903

1/1



2212903

TWO PHASE FLOW IN PIPES

The invention relates to the detection and analysis of two phase flow in pipes. By two phase flow is meant a mixture of gas with liquids or solids in a fluid state.

Two phase flows may arise due to cavitation in fuel systems at altitude on gas turbine engines. It was also applicable as a diagnostic tool in performance of pressure-scavenge lubrication systems in gas turbines to determine oil/air ratios.

These problems had periodically arisen in the course of engine development but they have never been successfully understood. Tactical efforts had been made to solve the problem by modifying the pipework and inserting transparent sections. High speed cine had been used but with little success.

Another important application for this technology would appear to lie in the field of subsea pumping systems. At present, reservoir fluid is taken direct from the well to an offshore platform where it is processed by separating the water and gas before pumping it or shipping it ashore. There is being developed a system to pump the gas, liquid and solids, such as sand, together, direct from the well to the shore or between platforms over a distance of possibly 50 miles on the seabed.

This technology of multiphase pumping could cut the cost of offshore exploration and development by 20% or more so that oil producers could develop marginal fields which they have hitherto refused to explore and develop due to high cost risk.

Apart from the pumping problem there is a metering problem at two levels; the oil field management problem with a required accuracy of say 5% and the fiscal metering problem with an accuracy of 0.1%. Presently the required fiscal accuracy is achieved with great difficulty after separation. Thus a two phase flow metering system is urgently required to complement the two phase flow pumping system.

The invention has for an objective to provide a device using an x-ray source and an imaging system to clip-on to a pipe and obtain images from which the nature and magnitudes of the internal flows could be deduced.

According to the invention there is provided apparatus for measuring two phase flow in a pipe including an x-ray device for x-raying a length of the pipe, means for determining the density distribution of material in the pipe and mean responsive to said density distribution to define the flow regime within the pipe.

Preferably the means responsive to the density distribution is arranged to compute the proportions of gas, liquids and solids in the pipe.

In an embodiment of the invention the x-ray device comprises a stereographic imaging system in which the two image forming paths preferably are oriented at a right angle one to the other about the axis of the pipe.

The invention and how it may be carried out in practice will now be described by way of example with reference to the accompanying drawing which illustrates, in diagrammatic form, a high energy x-ray imaging system for photogrammatic measurement of multiphase flow in a pipeline.

The system shown in Figure 1 comprises an intelligent instrumentation system to measure complex multiphase flows on the basis not only of the physical parameters but also the knowledge associated with such phenomena. It comprises a radiographic electron linear accelerator capable of 1,000 pulses per second providing sufficient radiation per pulse to provide a well exposed image on each frame of a high speed video system (1). The 'linac' emits a beam of high energy x-rays (2) which pass through a steel pipe line containing flowing oil and natural gas bubbles (3).

An image is formed, in one embodiment, on a large format phosphor screen which scintillates under the action of x-rays. The visible light image so formed is relayed via a mirror and relay optics and focused by a lens upon a light intensifier (6). Alternatively at smaller scale the image is converted from x-rays to light by means of a proprietary x-ray intensifier such as that manufactured by Thomson-CSF or Philips.

The light image is viewed by a high speed video camera (7) which is part of a high speed video system (8) such as the Kodak Spin Physics SP2000 and displayed on a monitor where it may be analysed.

In operation, the gas/liquid flows will be sampled as required at regular intervals by the system. The images will be stored on video tape.

Samples of images may be abstracted at will from the tape to video disc and sequences inspected in the photogrammetry system and/or held in frame stores for this purpose.

First the image will be held in frame store (9) whilst it is manipulated by an intelligent image processing system. It is then analysed with densitometry to determine gas/liquid from experts (10) on the spatial distribution of such reference interfaces as a pattern. This will define the flow regime ie. bubbly, slug/plug, churn, annular etc. This pattern will be automatically matched and recognised and define the flow type in the pipes and thus the relevant area in the flow regime map.

The second computer is essentially an intelligent real time photogrammetry system (11) (12). It will similarly take the spatial distribution of interfaces and compute from density information the gas/liquid/solid volumes in unit length of pipe. Both computers for real time applications would either be based on array or parallel processing or transputer technology. From an inspection of subsequent images, and by correlating flow structures in sequential image frames, the flow velocity may be determined and thus the gas and liquid flowrates. For more precise data a second linac and imaging system could if necessary be used in one embodiment at right angles to more closely define, in three dimensions, the bubble shapes. This is known as biplanar x-ray imaging.

Finally, the regime identified is entered into a multiphase flow intelligent knowledge based expert system (14) which makes decisions and then calls into operation the regime-specific software flow computational programs to provide the flow data.

The measurements would also be entered into the expert system. Calling on the knowledge base, which may be constructed as a rule based system, the required data is produced in a form suitable for engineers to assess the flow performance of the oil field for management purposes to control the process and output, or more precisely as a fiscal flow measurement system. It could also give warning of exceptional conditions (such as a 3 km slug of natural gas) which could cause hazard to process equipment.

It is envisaged that his non-invasive diagnostic and measurement system could be installed on the oil delivery pipe, on the seabed, at depth. It would automatically monitor the presence, nature and quantities of multiphase flow in pipes, including solid content such as sand. Water content could also be identified. The electrical power could be provided by a fuel cell and the system would be transmitted by cable or fibre-optics to the oil field management control centre.

The proposed system provides a capability which presently does not exist, namely non-invasive, real-time or near real-time multiphase flow diagnostics and measurement.

CLAIMS

1. Apparatus for measuring two phase flow in a pipe including an x-ray device for x-raying a length of the pipe, means for determining the density distribution of material in the pipe and means responsive to said density distribution to define the flow regime within the pipe.

2. Apparatus as claimed in claim 1 wherein the means responsive to the density distribution is arranged to compute the proportions of gas, liquids and solids in the pipe.

3. Apparatus as claimed in claim 1 or claim 2 wherein the x-ray device comprises a stereographic imaging system.

4. Apparatus as claimed in claim 3 wherein the stereographic x-ray system has two image forming paths oriented at a right angle one to the other about the axis of the pipe.

5. Apparatus substantially as described with reference to the accompanying drawing.

Published 1989 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office. Sales Branch, St Mary Cray, Orpington, Kent BR5 3RD. Printed by Multiplex techniques ltd, St Mary Cray, Kent, Con. 1/87